Wind-directed Pheromone Trap for Drone Honey Bees (Hymenoptera: Apidae)

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ABSTRACT A portable pheromone-trap system was developed for monitoring drone honey bee, *Apis mellifera* L., populations. The wind-directed system included a white nylon net, pheromone lure (porous polyethylene rod treated with synthetic *E*-9-oxo-2-decenoic acid [9-ODA]), 6.1-m support, and sample bag holder. The trapping site and anemotactic flight behavior of drones affected capture rates. Traps baited with 5 or 10 mg synthetic 9-ODA routinely captured 150–300 drones per 3 min during the 90-min periods of peak flight. Nonreusable lure components, including 5 mg synthetic 9-ODA, cost approximately one-fourth of the minimum price for two virgin queens. This trap system has potential as a survey and management tool for Africanized honey bee suppression programs and for control of local drone populations by queen breeders.

KEY WORDS pheromone trap, synthetic 9-ODA, drone, *Apis mellifera*

MOST KNOWLEDGE of drone honey bee, *Apis mellifera* L., mating-flight behavior is derived from visual observations of drones leaving and entering the hive and responses of flying drones to tethered queens, queen models, or sex-pheromone-treated lures suspended from balloons or poles (Gary 1963, Taylor 1984, Ruttner 1985). By suspending queens and pheromone lures from a meteorological tower, Butler & Fairey (1964) demonstrated that the flight altitude of drones is correlated inversely with wind speed. Boch et al. (1975) reported that lures treated with synthetic queen sex attractant, *E*-9-oxo-2-decenoic acid (9-ODA), are as attractive to flying drones as virgin queens. Strang (1970) found that flying drones discriminate among lures of different sizes, shapes and colors.

Recently, efforts have been made to quantify drone population dynamics by trapping drones on the wing. Gerig & Gerig (1983) captured drones in congregation areas with a net towed by a radio-controlled model airplane, and Taylor (1984) described an aerial trap for measuring parameters of drone flight behavior, including flight distance, the size of congregation areas, and drone density in congregation areas.

A suitable trap system could be used to evaluate the potential of synthetic queen sex attractant for monitoring and controlling local drone populations and for area-wide suppression of undesirable Africanized honey bee populations. Therefore, I developed a trap system for drone honey bees, which included a lure baited with synthetic queen sex attractant; a simple, portable trap support; and a rapid method of storing captured drones.

Materials and Methods

The operational trap system included a top-opening net, pheromone lure, portable support, and sample bag holder (Fig. 1). Field testing of trap-system designs began in mid-May, 1985. Early designs included one or more traps suspended between two 6.1-m fiberglass poles and a fixed-top net. Modifications for rapid transfer of captured drones to storage bags and a side-arm support pole were included in the final design (Fig. 1).

The net (Fig. 2), adapted from the design of Taylor (1984), was constructed of white nylon netting supported by three wire rings (bottom and middle rings, 50 and 35 cm in diameter, 0.014-cm-diameter stainless steel; top ring, 0.09-cm-diameter steel piano wire with a 29-cm section of piano wire soldered to it, forming a "jaw"). The net dimensions were 104 cm long by 50 cm in diameter (mouth) by 22.5 cm in diameter (top). Clear nylon monofilament fishing line was used as the trap support line (18.17-kg test), and for net attachment points for the net, lure cage, and decoys (6.36-kg test). Four drone decoys (blackened cigarette filters, 2.4 by 0.7 cm) were attached inside the net by fishing line (18 cm) and two drone decoys were attached by a 15-cm line to the bottom wire ring.

The lure cage (Fig. 2) was a small cylinder of galvanized hardware cloth (8 cm long by 2.2 cm in diameter, 8 mesh per cm) with a polyethylene vial cap in each end. A lure of white porous polyethylene rod (2.5 cm long by 0.64 cm in diameter, 70-μl pore size), treated with synthetic 9-ODA, was

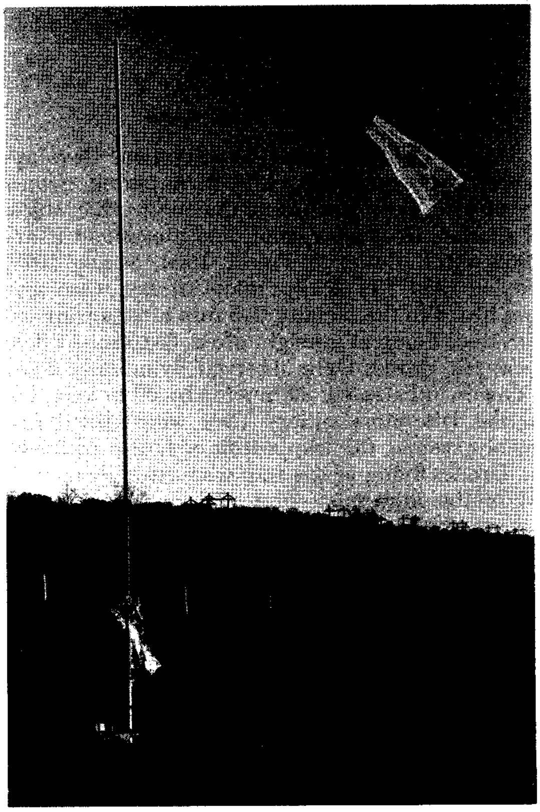

Fig. 1. Wind-directed pheromone-trap system for drone honey bees.

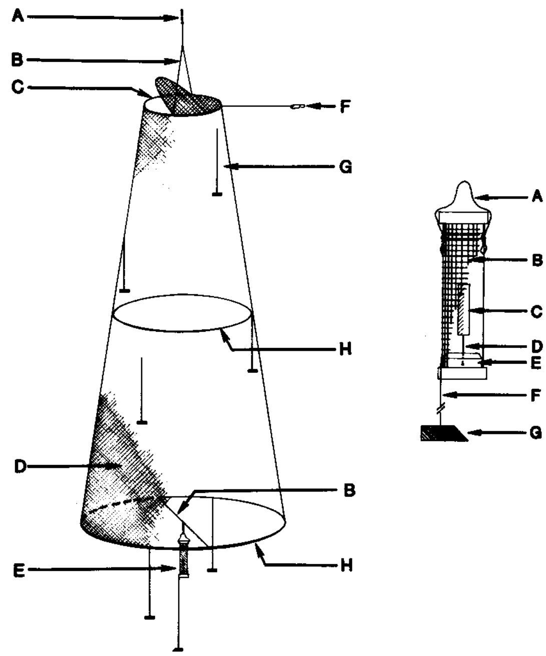

Fig. 2. Pheromone trap for drone honey bees (left): (A) snap swivel, (B) nylon monofilament line, (C) "jawed" ring (steel piano wire), (D) net bag (white nylon netting), (E) pheromone lure, (F) wire clasp, (G) drone decoy on nylon monofilament line, (H) stainless-steel wire rings. Pheromone lure (right): (A) support wire, (B) hardware-cloth cylinder, (C) lure of white porous polyethylene rod, (D) insect pin, (E) polyethylene vial cap, (F) nylon monofilament line, (G) queen decoy.

held inside the cage by a number 4 insect pin inserted through the cap. A queen decoy (blackened cigarette filter, 2.2 by 0.7 cm, tapered 45° on one end) was attached by a 25-cm line to the lower end of the lure cage.

The trap support (Fig. 3) consisted of steel pipe (51 cm long by 4.0 cm inside diameter) screwed into a steel pipe base bolted to a plywood square (0.61 m^2 by 1.9 cm thick), a 6.1-m-long fiberglass pipe (3.81 cm outside diameter by 0.7 cm thick) inside the steel pipe, and about 25 m of monofilament line. A teflon sheet (ca. 8 cm^2 by 1.5 mm thick) was stapled to the plywood base beneath the pipe base and adhesive teflon tape was applied to the inner surface of the uppermost 2 cm of the steel pipe. The trap support was weighted with two or three concrete blocks (ca. 6.5 kg each). A holder for plastic collection bags consisted of a triangular galvanized steel sheet, necked at the top to slide under a metal hose clamp and folded along the bottom edge to hold a 32-cm 9-gauge galvanized steel wire. The fiberglass sidearm rod was inserted through a hole drilled 2.5 cm from the upper end of the fiberglass pipe. A steel ring was attached near each end of the sidearm. During collections, a numbered, clear polyethylene bag (30.5 by 20.3 by 76.3 cm) was fastened to the bag support with two snap-type clothespins.

Teflon surfaces at points C and J (Fig. 3) allowed free rotation of the support pole inside the steel pipe. Wind pressure on the net bag maintained the trap in a downwind position. Initially, using fixed-top traps, drones were counted as they flew out of the net. With top-opening traps, captured drones were transferred to clear plastic bags by pulling the plastic bag (open end) down over the top of the net (ca. 30 cm), and then, from outside the plastic bag, separating and holding the jaws vertically with the other hand. The few drones that did not move rapidly from the net into the storage bag were transferred by hand.

Initial work in early June 1985 showed that drones flying within our main apiary readily entered pheromone traps attached to a nylon monofilament fishing line stretched between two 6.1-m poles. During midafternoon, 150–300 drones per trap routinely were collected in two traps within 3–5 min. However, a more portable type of support such as a single pole with a sidearm (Fig. 3) was desirable for field studies.

Relative trap effectiveness at extra-apiary sites was tested by trapping at two locations on the Ben

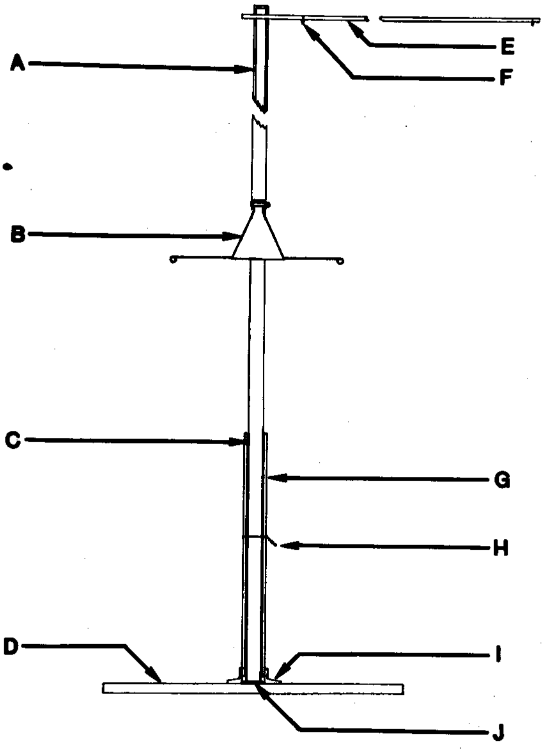

Fig. 3. Portable rotating support for drone honey bee pheromone trap: (A) fiberglass pipe, (B) support for collection bag, (C) adhesive teflon tape, (D) plywood base, (E) fiberglass rod, (F) steel ring, (G) steel pipe, (H) snap swivel, (I) steel base plate, (J) teflon sheet.

Hur Farm of the Louisiana Agricultural Experiment Station, Baton Rouge, along a canal 600 m south of the laboratory apiary, and along a wide grass lane leading from the canal bank to another apiary (Miller) 3 km south of the laboratory apiary. Traps were supported by monofilament lines attached to the midpoint of a horizontal monofilament line (ca. 45 m long) between two 6.1-m poles. Wind caused the height of the trap mouth above ground to vary from ca. 3.7 to 4.9 m. Observation dates were 13, 14, and 21 June 1985. Trapping stations along the canal were at ca. 50 (trap 1), 200 (trap 2), and 350 m (trap 3) southeast of Ben Hur Road. Lures were treated with fresh sex attractant (10 mg 9-ODA each) daily before trapping. After the side-arm trap support was designed, collections were made along the wide, 1,600-m grass lane that divided a large cornfield south of the canal. Here, four wind-directed traps (Fig. 1) baited with 5 mg 9-ODA per lure were operated on 9 July 1985, at 200 (trap 1), 600 (trap 2), 1,100 (trap 3), and 1,500 m (trap 4) from the canal bank. Traps 3 and 4 were also 500 and 100 m north of the Miller apiary (15 10-frame Langstroth colonies and ca. 20 nucleus colonies). Apiary 3 (25 10-frame Langstroth colonies) was west of trap 1 (966 m) and trap 2 (942 m); and apiary 4 (21 10-frame Langstroth colonies) was northeast of trap 1 (1,600 m).

Results and Discussion

Drone Behavior and Trap-system Development. Upon contacting a 9-ODA plume, drones fly upwind until they see a queen or other object of similar size, shape, color, and movement (Gary 1963, 1971, Butler & Fairey 1964, Strang 1970, Taylor 1984). Typically, many drones were seen and heard in the vicinity 0–5 min after a trap was elevated, flying at a height of ca. 3–15 m. At field locations, drones were observed flying only along a downwind area ca. 20 m wide by 60 m long, but in the laboratory apiary they were distributed evenly around the trap within a radius of 50–60 m. Drones flying near a trap were strongly attracted to the movement of the three black decoys hanging below the net, especially the more actively moving queen decoy. Periodically, drones approached the queen decoy, flew upward into the top of the net, and remained there. Captured drones began to fly less vigorously after ca. 15 min and gradually either landed on the net and walked out or flew out directly. Occasionally, drones flew near or touched the lure cage, became contaminated with 9-ODA and were pursued by clusters of ca. 20–100 drones. At times, two to five of these drone "comets," similar to those attracted to a tethered queen (Gary 1963), were observed within a 150-m radius of a trap.

The present trapping system was used in most wind speeds at which drones fly (0–7.2 m/s). However, traps were difficult to operate during windy weather without a restraint. Trap operation was improved in winds >3 m/s by adding a tether line (Taylor 1984) or two lead fishing weights (7–14 g) to the bottom net-ring.

Based on these results and other similar observations, a single pole support was designed, which rotated freely under wind pressure on the trap, constantly angling the trap away from the pole during periods of air movement.

Site Differences. Three traps operated at 150-m intervals along the canal site ca. 600 m from the laboratory apiary and within flight distance of three other apiaries (total of 111 multistory 10-frame Langstroth colonies) had markedly different capture rates according to position in the trap line (Table 1). The unit farthest downwind (trap 1) caught few drones on all 3 d; trap 2 caught 1,052 drones on day 2, but only 120 after the third unit was added (day 3). On day 3, the unit farthest upwind (trap 3) again had most (80%) of the total catch. The consistently low capture rate indicated that station 1 was not an attractive location. In preliminary tests with closely spaced traps (12.8 m), anemotactic behavior of drones was evident. Similarly, at a spacing of 150 m, the trap located farthest upwind in the trap line coincident with

Table 1. Response of drones to pheromone traps located 150 m apart on a line coincident with prevailing winds, 1985

Date	No. 3-min periods	No. drones captured/trap		
		Trap[a]		
		1	2	3
13 June	9	20	—[b]	—
14 June	11	65	1,052	—
21 June	11	75	120	793

[a] Single traps suspended from monofilament line between two poles. Weather data means for trapping periods: in order, air temperature (°C), wind speed (m/s), and light intensity (lux × 10^3); 13 June, 29.4, 1.7, 12; 14 June, 27, 2.9, 11.2; 21 June, 29.2, 2.9, 5.6; wind direction from trap 3 to trap 1.

[b] —, trap not operated.

Table 2. Number of drones captured per 3 min in pheromone traps within flight range of four apiaries, 9 July 1985

Starting time (hours CST)	Trap[a]			
	1	2	3	4
1550	267	—[b]	—	—
1600	289	—	191	—
1614	225	287	36	46
1624	210	289	132	6
1634	324	96	134	42
1644	231	74	52	18
1654	68	118	82	11

[a] Wind-directed traps baited with 5 mg 9-ODA located along a straight 1,600-m lane bisecting a large cultivated area and on line with two apiaries. Weather data means for trapping periods: air temperature, 34.3°C; wind speed, 1.5 m/s; light intensity, 11.9 × 10^3 lux.

[b] —, trap not operated.

prevailing wind direction caught the most drones. Thus the large amounts of 9-ODA (10 mg/lure) used apparently created a pheromone plume longer than the theoretical plume length of 60 m presented by Butler & Fairey (1964).

On 9 July 1985, four pheromone traps on a 1,400-m long trap line along the cornfield lane perpendicular to the midpoint of the canal site had a combined catch (69 min total trap time) of 3,238 drones (Table 2). Catches were reflected in trap distances from the largest drone population (laboratory apiary). Relative catches and approximate distances from the laboratory apiary (probable source of most of the drones) to the cornfield traps were: traps 1 (800 m) and 2 (1,200 m), 77.5%; trap 3 (1,700 m), 17.5%; and trap 4 (2,100 m), 5%. The small catches by traps 3 and 4 at 400 and 100 m from the Miller apiary, respectively, agreed with the minimal drone flight activity observed at the entrances of colonies in the apiary for 2 wk before the collections. Possible causes of the differential catches here include random distribution of flying drones, giving largest catches near the primary drone source (laboratory apiary); and presence of a congregation area (Ruttner 1985) encompassing traps 1 and 2 near the cornfield lane and canal intersection.

In this study, lures were treated with excessive amounts of 9-ODA (5 or 10 mg each) (Strang 1970) to ensure maximum attractiveness during less favorable conditions of midseason (i.e., lower wind speeds, higher temperatures, and declining drone populations).

Taylor (1984), using two caged queens suspended below the net mouth, found that traps ≥10 m above ground level were most effective under cloudless skies at 24–32°C and when winds (1.9–6.9 m/s) were from the direction of the sun. He reported that drones were attracted to queens only in drone congregation areas. In South Africa, both queens and synthetic 9-ODA attracted *Apis mellifera scutellata* drones at congregation areas and at points between congregation areas and apiaries (Tribe 1982). Boch et al. (1975) found that numerous drones were attracted to natural or synthetic 9-ODA, or queens, elevated 5 m over most of a 500-ha area in the vicinity of managed colonies. In June and early July at Baton Rouge, pheromone traps also elevated ca. 5 m routinely caught 150–300 drones per 3 min within an apiary and at various distances within flight range of four apiaries. However, few drones were attracted to the pheromone traps at any location when winds were ca. 0.5 m/s or less.

Although the mechanism of congregation-site selection by drones is incompletely understood, terrain is thought to influence strongly direction and distance of drone mating flights (Ruttner 1985). In mountainous or hilly regions, drones fly to and congregate at breaks in the horizon, including saddles and openings in forested areas. Besides terrain, the number of available drones, wind direction and speed, and season of the year are considered to regulate the density, size, and location of congregation areas (Strang 1970, Tribe 1982, Ruttner 1985). In addition, Loper (1985) theorized that variation in the earth's electromagnetic field may be important in the selection of congregation sites by drones. Another possible regulator of drone flight behavior is the sound produced by flying drones (Es'kov 1972, 1973). Regardless of the physical cues involved, drone flight apparently is quite directional whether it is over flat, hilly, or mountainous terrain (Tribe 1982, Ruttner 1985; unpublished data). The pheromone trap system reported here is expected to facilitate studies of the directionality of drone flight and the relation of environmental parameters to congregation area selection by drones.

Synthetic 9-ODA. Presently, lures treated with synthetic 9-ODA are superior both in uniformity and cost to virgin queens as baits for drone traps. Boch et al. (1975) demonstrated that variation in attractiveness of tethered queens was related to the amount of extractable 9-ODA per queen (22–325 μg) and that virgin queens contain less 9-ODA than mated ones. Consequently, two virgin queens per trap are needed to ensure attractiveness (Taylor 1984). The major advantage of artificial lures for drone trapping involves the cost of materials; 5 mg synthetic 9-ODA ($0.45) and other expendable items were ca. 25% of the 1986 minimum price for two virgin queens ($2–5 per queen). Moreover, the cost of 9-ODA for potential large-scale Africanized honey bee control programs involving drone trapping will be insignificant if additional studies show that amounts of the synthetic sex attractant similar to the maximum produced by queens give satisfactory trap performance, and the price of the synthetic pheromone does not increase substantially.

In limited mid- to late-season trials during 1985, 9-ODA traps consistently caught 150–300 drones per 3-min trapping period at some stations. Thus, the theoretical catch of four traps continuously operated over the daily 90-min period of maximum drone flight might be as many as 18,000–36,000 drones. By operating clusters of traps at selected locations and temporarily restricting flight of desired drone stocks, queen producers may be able to manage flying drone populations sufficiently to achieve a high rate of desired matings. However, evaluation of the drone traps as a means of controlling natural queen mating requires a trap design that retains or kills captured drones; and a method of identifying drone congregation areas or other sites where the drone population of an area can be trapped efficiently.

This pheromone trap or a modified version has potential for use in Africanized honey bee control programs in Latin America and, if needed, the United States. The major limiting factor in the development of pheromone traps as an Africanized honey bee survey and management tool appears to be the availability of synthetic 9-ODA.

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